IS OPERA NEUTRINO SUPERLUMINAL PROPAGATION SIMILAR TO GAIN-ASSISTED SUPERLUMINAL LIGHT PROPAGATION

Vladan Panković,
Department of Physics, Faculty of Sciences, 21000 Novi Sad,
Trg Dositeja Obradovića 4, Serbia,
vladan.pankovic@df.uns.ac.rs

Abstract

In this work we consider a possible conceptual similarity between recent, amazing OPERA experiment of the superluminal propagation of neutrino and experiment of the gain-assisted superluminal light propagation realized about ten years ago. Last experiment refers on the propagation of the light, precisely laser pulse through a medium, precisely caesium atomic gas, with characteristic anomalous dispersion and corresponding negative group-velocity index with very large amplitude between two closely spaced gain lines (that is in some way similar to quantum theory of the ferromagnetism). It implies superluminal propagation of the light through this medium. Nevertheless all this, at it has been pointed out by authors, "is not at odds with causality or special relativity", since it simply represents "a direct consequence of the classical interference between different frequency components". We suggest that OPERA experiment can be in some way conceptually similar to the gain-assisted superluminal light propagation experiment. For this reason we suppose too that OPERA experiment can be simply explained in full agreement with causality and special relativity if there is some medium, precisely a scalar field (e.g. dark matter field, Higgs field or similar) through which neutrino propagates. We prove that, according to OPERA experiment data, supposed medium must be non-dispersive while its refractive index must be positive, smaller but relatively close to 1 (that is in some way similar to quantum theory of the diamagnetism). If it is true OPERA experiment results do not mean that special theory of relativity is broken, but they mean detection of suggested medium, i.e. a scalar field (e.g. dark matter field, Higgs field or similar).

PACS number: 12.15.-y, 13.15.-g

In this work we shall consider a possible conceptual similarity between recent, amazing OPERA experiment of the superluminal propagation of neutrino [1] and experiment of the gain-assisted superluminal light propagation [2] realized about ten years ago. Last experiment

refers on the propagation of the light, precisely laser pulse through a medium, precisely caesium atomic gas, with characteristic anomalous dispersion and corresponding negative group-velocity index (very large amplitude between two closely spaced gain lines) that implies superluminal propagation of the light through this medium. (It is in some way similar to quantum theory of the ferromagnetism according to which relative magnetic permeability becomes large in a narrow boundary between two domains.) Nevertheless all this, at it has been pointed out by authors, "is not at odds with causality or special relativity", since it simply represents "a direct consequence of the classical interference between different frequency components". We shall suggest that OPERA experiment can be conceptually similar to the gain-assisted superluminal light propagation. For this reason we shall suppose that OPERA experiment can be simply explained in full agreement with causality and special relativity if there is some medium (a scalar field, e.g. dark matter field, Higgs field or similar) through which neutrino propagates. We shall prove that, according to OPERA experiment data, supposed medium must be non-dispersive while its refractive index must be positive, smaller but relatively close to 1. (It is in some way similar to quantum theory of the diamagnetism which needs that orbital momentum of the diamagnetic atoms must be exactly equivalent to zero and which predicts that relative magnetic permeability is smaller but relatively close to 1.) If it is true OPERA experiment results do not mean that special theory of relativity is broken, but they mean detection of suggested medium, i.e. a scalar field (e.g. dark matter field, Higgs field or similar).

About ten years ago Wang, Kuzmich and Dogariu [2] realized experiment of the gain-assisted superluminal light propagation whose basic elements (including corresponding theory) we shall now shortly repeat. As it is well-known in a dispersive linear medium with optical refractive index $n(\nu)$ depending of the optical frequency ν light pulse with this frequency propagates with the group velocity $v_g = \frac{c}{n_g}$ where $n_g = n(\nu) + \nu\frac{dn(\nu)}{d\nu}$ represents the group-velocity refractive index and $c = 299792\text{km/s}$ - speed of light. In domain between two closely spaced gain lines there is an anomalous dispersion region where $\nu\frac{dn(\nu)}{d\nu}$ is negative with extremely large amplitude. (It is in some way similar to quantum theory of the ferromagnetism according to which relative magnetic permeability becomes large in a close space between two domains.) In this situation expression

$$\Delta T = \frac{L}{v_g} - \frac{L}{c} = (n_g - 1)\frac{L}{c} \tag{1}$$

that represents time difference between propagation time of the light pulse through medium with length L and propagation time of the light pulse through vacuum with the same length L, becomes negative too. It means that light pulse propagates through medium effectively superluminally, i.e. faster than propagation of this pulse through vacuum (pulse time advancement shift). Nevertheless all this, at it has been pointed out by authors, "is not at odds with causality or special relativity", since it simply represents "a direct consequence of the classical interference between different frequency components" [2]. "Remarkably, the signal velocity of a light pulse, defined as the velocity at which half point of the pulse front travels, also exceed the speed of light in vacuum, c, in present experiment. It has also been suggested that the true speed at which information is carried by a light pulse should be defined as the "frontal" velocity of the step-function-shaped signal which has been shown not to exceed c."[2] In experimental realization of this theory Wang, Kuzmich and Dogariu used gaseous medium of the caesium atoms any of which has one excited state and two (close) ground states and corresponding polarized

laser beam and obtained pulse advancement shift $\Delta T = 62ns$ or $n_g = -310$ for $L = 6cm$.

In recent OPERA experiment [1], in agreement with some other earlier experiments on the superluminal neutrino propagations [3], there is a pulse of muon neutrinos that propagates along base line

$$L = 730534.61m \tag{2}$$

, with time difference with respect to the one assuming the speed of light in vacuum

$$\Delta T = -60.7ns \tag{3}$$

or with relative difference of the muon neutrino velocity v with respect to the speed of light

$$\frac{v - c}{c} = 2.4810^{-5} \tag{4}$$

corresponding to

$$v = (1 + 2.4810^{-5})c = 1.0000248c. \tag{5}$$

It represents an extremely unexpected result whose theoretical explanation in this moment is unknown. For example Amelino-Camelia group [4] supposes that OPERA data can be explained by special-relativistic tachyons, etc.

We shall originally and simply suppose that OPERA experiment is in some way conceptually similar to the experiment of the gain-assisted superluminal light propagation. Really, many characteristics of the neutrinos are very similar to the characteristic of the photons. But it can be observed that in the experiment of the gain-assisted superluminal light propagation there is characteristic medium, precisely caesium atomic gas, with characteristic anomalous dispersion and corresponding negative group-velocity index, while in the OPERA experiment similar medium, at the first sight, does not exist. However, it can be observed that a scalar field, e.g. dark matter field, Higgs field or similar, can exist. This field seems practically identical to any observer, moving or rest, and mimics vacuum. Moreover, as it has been pointed out by Linde (in the chaotic inflation cosmology [5], [6]) such field can during time occupy practically whole space or, at least, our galaxy, Sun system and Earth. Finally, a quantized scalar field has quantums with zero spin representing bosons.

If such suggested scalar field really exists and if it has some group velocity refractive index for neutrino, this refractive index in OPERA experiment, according to (1), (2), (3), equals

$$n_g = 0.975. \tag{6}$$

It represents a positive refractive index smaller but relatively close to 1. All this is in some way similar to quantum theory of the diamagnetism which predicts that relative magnetic permeability is smaller but relatively close to 1 and which needs that orbital momentum of the diamagnetic atoms must be exactly equivalent to zero. If this similarity has any sense it would mean that quantums of mentioned scalar field hold zero spin in full agreement with general quantum theory of the scalar fields.

Also, according to OPERA experiment data, there is no dependence between ΔT or n_g and neutrino energy or (de Broglie) frequency, which means that suggested medium must be non-dispersive.

Finally, it can be observed that introduced hypothesis on the scalar field representing non-dispersive medium for neutrinos, admits that, like in case of the gain-assisted superluminal light propagation, superluminal propagation of the neutrinos be explained in simple way that "is not at odds with causality or special relativity", since it simply represents, we paraphrase, "a direct consequence of the wave characteristics" of neutrino.

In conclusion we shall shortly repeat and point out the following. In this work we consider a possible conceptual similarity between recent, amazing OPERA experiment of the superluminal propagation of neutrino and experiment of the gain-assisted superluminal light propagation realized about ten years ago. Last experiment refers on the propagation of the light, precisely laser pulse through a medium, precisely caesium atomic gas, with characteristic anomalous dispersion and corresponding negative group-velocity index (with very large amplitude between two closely spaced gain lines) that implies superluminal propagation of the light through this medium. (It is in some way similar to quantum theory of the ferromagnetism according to which relative magnetic permeability becomes large in a narrow boundary between two domains.) Nevertheless all this, at it has been pointed out by authors, "is not at odds with causality or special relativity", since it simply represents "a direct consequence of the classical interference between different frequency components". We suggest that OPERA experiment can be in some way conceptually similar to the gain-assisted superluminal light propagation. For this reason we suppose too that OPERA experiment can be simply explained in full agreement with causality and special relativity if there is some medium, precisely a scalar field (e.g. dark matter field, Higgs field or similar) through which neutrino propagates. We prove that, according to OPERA experiment data, supposed medium must be non-dispersive while its refractive index must be positive, smaller but relatively close to 1. (It is in some way similar to quantum theory of the diamagnetism which needs that orbital momentum of the diamagnetic atoms must be exactly equivalent to zero and which predicts that relative magnetic permeability is smaller but relatively close to 1.) If it is true OPERA experiment results do not mean that special theory of relativity is broken, but they mean detection of suggested medium, i.e. a scalar field (e.g. dark matter field, Higgs field or similar).

References

[1] T. Adam, N. Agafonova, A. Aleksandrov et al, *Measurement of the Neutrino Velocity with the OPERA Detector in the CNGS Beam*, hep-ex/1109.4897

[2] L. J. Wang, A. Kuzmich, A. Dogariu, Nature **406** (2000), 277

[3] P. Adamson et al, [MINOS collaboration], Phys. Rev. **D76** (2007) 072005; hep-ex/0706.0437

[4] G. Amelino-Camelia et al, *OPERA-reassessing Data on the Energy Dependence of Speed of Neutrinos*, hep-ph/1109.5172

[5] A. D. Linde, in, *300 Years of Gravitation*, eds. S. W. Hawking and W. Israel (Cambridge University Press, Cambridge, England, 1989)

[6] A. D. Linde, *Inflation and Quantum Cosmology* (Academic Press, Boston, 1990)